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(54) Method for making a substantially planar construction of resin impregnated fabric.

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## Description

This invention relates to the manufacture of resin impregnated fabric articles which are useful as dielectric substrates in printed circuit boards and to improvements in said manufacturing of such articles which avoid shrinking of the articles during final curing of the resin.

It has long been known to use resin impregnated fabric, more commonly known as prepreg, as a dielectric substrate in the manufacture of printed circuit boards.

In a typical process, the fabric, which may be made from any suitable material, is coated with a curable resin. The resin is then partially cured, or "B-staged", in order to provide substantially planar cards or boards of prepreg which can be used to construct a printed circuit board. Typically the prepreg comprises glass cloth impregnated with an epoxy resin as is shown in U.S. Patent No. 3,660,199.

Often, prior to personalization of the printed circuit board, the prepreg components are laminated together to form thicker dielectric layers and are sometimes sandwiched between layers of a conductive material. The conductive layers are then sometimes covered with additional layers of prepreg to form buried conductive layers.

It is also typical in the manufacture of printed circuit boards having one or many layers to make holes, known as through holes, completely through the printed circuit board. The holes are made by a variety of techniques such as drilling or laser cutting. They may be plated with a conductive material for use in electrical communication between the sides of the printed circuit board or they may be used to receive pins of components which are plugged into the printed circuit board.

Finally the prepreg or the drilled laminate is fully cured or "C-staged". C-staging after lamination helps to improve laminar adhesion in printed circuit boards comprising layers of prepreg. The C-staged prepreg or laminate is then normally personalized on at least one side with an electrically conductive circuit, which may be applied by any of a variety of well-known techniques, such as silk screen printing or photomasking combined with plating and etching.

It has been a problem with prepreg made by the process described above, especially when B-staged by heating in a vertical curing oven, that the prepreg shrinks during C-staging. Such shrinking is more dramatic when the prepreg is B-staged in a vertical drying oven, although it is also noted when the prepreg is B-staged in a horizontal oven. It is believed that the weight of the resin coated web as it is pulled up the vertical curing oven or through a horizontal oven stresses the warp of the fabric. It is

believed that during C-staging the forces exerted by the warp in trying to recover from this stress causes the prepreg to shrink in a direction parallel with the warp.

Such shrinking causes through holes drilled in the prepreg, or in a laminated substrate comprising such prepreg, to move toward the center of the board during C-staging.

Coping with this problem has been a major factor in the production of printed circuit boards. Generally the shrinkage is compensated for by the complex and imprecise technique of anticipating shrinkage, such as by making through holes in locations other than where they are ultimately desired in anticipation that they will move to the desired location.

There is a need for prepreg which demonstrates reduced shrinkage during C-staging.

The invention as claimed provides a method for making substantially planar constructions of resin-impregnated fabric, which method comprises the steps of (1) coating the fabric with a curable resin, (2) partially curing the resin and (3) fully curing the resin. The method comprises, between steps (2) and (3), cutting at least a plurality of the warp of the fabric in at least one location, whereby shrinkage of the construction during step (3) is reduced.

The invention is described in detail below with reference to the drawings of which

FIG. 1 shows schematically and in cross-section an apparatus for making prepreg.

FIG. 2 shows a top view of a B-staged printed circuit board made employing the present invention.

FIG. 3 shows a top view of a B-staged printed circuit board made employing a preferred embodiment of the present invention.

FIG. 4 shows schematically and in cross-section a printed circuit board made in part of laminated layers of prepreg employing the present invention.

It has been discovered that cutting at least a plurality of the warp of the resin-impregnated fabric in at least one location while the resin is in a partially cured state will surprisingly reduce the shrinkage of the prepreg during C-staging.

Referring more specifically to FIG. 1, there is shown a greatly simplified apparatus for coating a fabric with resin and for B-staging the coated fabric.

Fabric 1 is unwound from supply roll 2 and dipped into a curable liquid resin 3 before entering curing oven 4 where the liquid coated fabric is partially cured, usually by forced hot air.

Any useful fabric and resin may be employed.

The particular type of resin and fabric used are not critical to the operation of the invention. Typically, fabric 1 is glass cloth and resin 3 is an epoxy or polyimide resin.

After exiting curing oven 4, the partially cured resin impregnated fabric, known as prepreg, is cut into panels 5 by cutter or slitter 6.

It is believed that the weight of the resin coated fabric 7 stresses the warp of fabric 1 as it is drawn up vertical curing oven 4, as explained above. Such stressing also occurs in systems having horizontal curing ovens (not shown), but to a lesser degree.

Referring more specifically to FIG. 2, there is shown a top view of a B-staged panel 5. A single, non-continuous line of cuts 8 has been made in the warp of the fabric which forms the core of panel 5. The warp of the fabric runs lengthwise of the panel. The cuts do not have to be in a line perpendicular to the warp as shown in FIG. 2, although such a configuration is normally preferred because of manufacturing convenience. The cuts could be at random locations or, for example, in a diagonal line or a curve. It is important to the operation of the invention that at least a plurality of the warp be cut in at least one location, but the pattern of the cuts in the warp is not critical.

Cuts 8 part just over half of the warp in panel 5. As will be more fully described in the following Example, it has been found that cuts in at least a plurality of the warp of the fabric in at least one location, one embodiment of which is shown in FIG. 2, will reduce the shrinkage of prepreg more than 20% during C-staging.

Cuts 8 may be made by any useful means. The means of making cuts 8 is not critical to the invention. For example, a knife edge, a laser or a roller embossed with a pattern of knife edges may be used. The cutting means normally cuts through the resin coating on one side of the fabric and through the warp of the fabric, leaving a slit in the resin which is "healed" during C-staging.

Through holes 9 and electrically conductive circuit 10 are applied to panel 5 by conventional and well known means which are described in the literature and which will not be repeated here. Normally through holes 9 are made before C-staging and circuit 10 is applied after C-staging.

Referring more specifically to FIG. 3, there is shown panel 5 in which 12 non-continuous cuts 8 have been made across a plurality of the warp of the fabric. As is discussed in more detail in the following Example, the number of cuts 8 shown in FIG. 3 provide about an 80% reduction in shrinkage of the prepreg during C-staging. Although it is not shown in this figure, either or both surfaces of panel 5 may be personalized with electrically conductive circuitry and through holes may be made in the panel, as is shown in FIG. 2.

Referring more specifically to FIG. 4, there is shown printed circuit board 11 which is made using the construction of the present invention. Printed circuit board 11 comprises a central core 13 of three laminated layers of prepreg 12 which includes the improvement of the present invention. Conductive layers 14 are on either side of central core 13 and are in turn covered by two additional layers of prepreg 12. Through holes 15 have been drilled through printed circuit board 11 and have been plated with an electrically conductive metal in order to enable electrical communication between printed circuits 17, which have been applied to both sides of printed circuit board 11.

Warp 18 and weft 19 of the fabric of prepreg 12 is shown impregnated in resin 20. Cuts 21 in warp 18 are also shown. Resin 20 around cuts 21 has healed during C-staging of printed circuit board 11 so that no slits in the resin remain.

Laminating of the various layers shown in FIG. 4, the deposition of a conductive metal on a dielectric resin and the drilling of through holes through multiple layers are well-known techniques in the art of making printed circuit boards.

The invention will be further illustrated by the following examples of which construction no. 1 is not in accordance with the present invention and constructions nos. 2-10 are examples of constructions made by the method of the invention.

## EXAMPLES

A dielectric substrate, also known as prepreg, for use in the manufacture of printed circuit boards was made by dip-coating a 60 cm-wide web of glass cloth, commercially available from Uniglass as Style 109 Glass Cloth, in a heat curable epoxy resin, commercially available from Ciba Geigy as FR 4. An Egan treater was used.

The glass cloth, coated with uncured epoxy resin was run through a 148°C vertical curing oven for 2 minutes to accomplish partial curing or "B-staging", of the resin. After leaving the oven, the web was cut into 70 cm-long boards by a Moore & White slitter.

The boards were used to make constructions having three layers of prepreg sandwiched between 70 µm copper layers which were in turn covered by two layers of prepreg. A pattern of about 2,500 through holes which is commonly used in the manufacture of printed circuit boards was drilled in nine such constructions, numbered 1 through 10, and the x and y locations of 30 of the through holes was recorded for future comparison.

### Construction No. 1

No cuts were made in Construction No. 1. It

was fully cured, or "C-staged", at 176 °C for an hour under  $34,5 \times 10^5$  Pa (34,5 bar) uniform pressure applied by a hydraulic press, and the x and y locations of the same 30 through holes were once again recorded and compared to their original locations. The outermost holes, near the 60 cm-wide edge of the board and located about 22,86 cm from the centerline of the board, were found to be drawn toward the centerline of the board, the movement being parallel to the 70 cm dimension, by about 127  $\mu$ m. The holes nearer the center of the board were drawn toward the center of the board by a lesser distance.

For uniformity of comparison from board to board, this movement may be expressed as parts movement per million parts distance from the hole location to the centerline of the board (ppm). In the case of Construction No. 1, there were 550 parts movement for each million parts distance, or 550 ppm.

#### Construction No. 2

Construction No. 2 was made, drilled and measured as in connection with Construction No. 1 except that each prepreg component of Construction No. 2 was subjected to one non-continuous cut across its warp by an exacto knife prior to assembly. The exacto knife was positioned to cut through the partially cured resin to a depth sufficient to part the warp of the glass cloth and was manipulated to cut only just over half of the warp in each component. An open slit the width of the knife thickness was also left in the resin at positions where the warp was cut.

Construction No. 2 was C-staged and the x and y locations of the same 30 through holes were recorded and compared to their locations before C-staging. Movement of the holes was reduced to about 420 ppm, a reduction of over 23%.

It was observed in Construction No. 2 and in Constructions 3 through 10, described below, that after C-staging the cut left in the resin by the exacto knife had been "healed", in most cases without a visible trace.

#### Construction No. 3

Each prepreg component of Construction No. 3 was subjected to two separate non-continuous cuts along the warp of the glass cloth. The cuts were evenly spaced to divide each component substantially in thirds and, as in Construction No. 2, each cut separated just over half of the warp. After being subjected to the same measurements and comparisons as Constructions 1 and 2, it was observed that in Construction 3 the migration of the holes was reduced to about 350 ppm, a reduction of over

36%.

#### Construction No. 4

Each prepreg component of Construction No. 4 was subjected to three separate non-continuous cuts along the warp of the glass cloth. The cuts were evenly spaced along the length of the component and, as before, parted just over half the warp. After being subjected to the same measurements and comparisons as Constructions 1 through 3, it was observed that in Construction No. 4 the movement of the through holes during C-staging was about 200 ppm, a reduction of over 63%.

#### Construction No. 5

Each prepreg component of Construction No. 5 was subjected to six separate non-continuous cuts along the warp of the glass cloth. The cuts were evenly spaced along the length of the component and, as before parted just over half the warp. After being subjected to the same measurements and comparisons as Constructions 1 through 4, it was observed that in Construction No. 5 the movement of the through holes during C-staging was about 180 ppm, a reduction in shrinkage of about 67%.

#### Construction No. 6

Each prepreg component of Construction No. 6 was subjected to nine separate non-continuous cuts along the warp of the glass cloth as in the previous Constructions 2 through 5. After being subjected to the same measurements and comparisons as Constructions 1 through 5, it was observed that in Construction No. 6 the movement of the through holes during C-staging was about 150 ppm, a reduction in shrinkage of about 70% over the shrinkage of Construction 1.

#### Construction No. 7

Each prepreg component of Construction No. 7 was subjected to 12 separate non-continuous cuts along the warp of the glass cloth as in previous Constructions 2 through 6. After being subjected to the same measurements and comparisons as Constructions 1 through 6 it was observed that in Construction No. 7 the movement of the through holes during C-staging was about 100 ppm, a reduction in shrinkage of about 80% over the shrinkage of Construction 1.

#### Construction No. 8

Each prepreg component of Construction No. 8 was subjected to 15 separate non-continuous cuts

along the warp of the glass cloth. As in previous constructions 2 through 7, the cuts parted just over half the warp in each component. After being subjected to the same measurements and comparisons as Constructions 1 through 7, it was observed that in Construction No. 8 the movement of the through holes during C-staging was about 100 ppm, a reduction in shrinkage of about 80% over the shrinkage of Construction 1, but no further improvement over the the shrinkage of Construction No. 7.

#### Constructions No. 9 and No. 10

Each prepreg component of Construction No. 9 was subjected to three separate non-continuous cuts along the warp of the glass cloth and three separate such cuts along the weft of the glass cloth. Each prepreg component of Construction No. 10 was subjected to 15 separate such cuts along the warp and 15 separate cuts along the weft of the glass cloth. Each cut parted just over half of the warp or weft.

After being subjected to the same measurements and comparisons as Constructions 1 through 8 it was observed that Construction No. 9 showed only marginally less movement of through holes than Construction No. 4 during C-staging and that Construction No. 10 showed no additional reduction in movement of through holes than Construction No. 8.

It will be clear to one of ordinary skill in the printed circuit board technology after reading the preceding Example that the improvement of the present invention can be used to reduce shrinkage or movement of through holes in prepreg and in printed circuit boards of a variety of sizes, comprising a variety of layers of prepreg and other materials and whenever said prepreg is made from a variety of resins and fabrics. It will also be apparent to such a technician that cutting of the fabric can be accomplished by a number of other methods, such as laser cutting or the use of a roller embossed with a pattern of knife edges.

#### **Claims**

1. Method for making a substantially planar construction of resin-impregnated fabric which comprises the steps of (1) coating the fabric with a curable resin, (2) partially curing the resin and (3) fully curing the resin, characterized by, between steps (2) and (3), cutting at least a plurality of the warp of the fabric in at least one location, whereby shrinkage of the construction during step (3) is reduced.
2. The method of Claim 1 wherein portions of the

weft of the fabric are also cut.

3. The method of Claim 1 wherein the warp is cut along at least one line which is substantially perpendicular to the warp.
4. The method of Claim 3 wherein the warp is cut sufficiently to reduce such shrinkage of the construction by about 80%.
5. The method of Claim 3 wherein the warp is cut in a non-continuous fashion.
6. The method of Claim 1 wherein, after cutting and prior to step (3), the substantially planar construction is laminated with at least one other planar member selected from the group consisting of other substantially similar constructions and a conductive metal in order to form a laminate.
7. The method of Claim 6 wherein after lamination and before step (3) at least one through hole is made in the laminate.
8. The method of Claim 1 wherein a printed circuit is applied to at least one surface of the construction.
9. The method of Claim 6 wherein the laminate has at least one outer surface of said substantially similar construction having a printed circuit applied thereto.
10. The method of Claim 1 wherein cutting is accomplished by a knife edge.
11. The method of Claim 1 wherein cutting is accomplished by the application of laser radiation.
12. The method of Claim 1 wherein the fabric is a glass cloth.
13. The method of Claim 1 wherein the resin is a heat curable epoxy resin.

#### **Revendications**

1. Procédé de fabrication d'une structure sensiblement plane en tissu imprégné de résine, qui comprend les opérations de (1) revêtement du tissu avec une résine durcissable, (2) durcissement partiel de la résine, et (3) durcissement complet de la résine, caractérisé en ce que, entre les opérations (2) et (3), on coupe au moins une pluralité des fils de chaîne du tissu à au moins un endroit, de sorte que la contrac-

- tion de la structure pendant l'opération (3) est réduite.
2. Procédé suivant la revendication 1, dans lequel des parties de la trame du tissu sont également coupées. 5
  3. Procédé suivant la revendication 1, dans lequel la chaîne est coupée suivant au moins une ligne qui est sensiblement perpendiculaire à la chaîne. 10
  4. Procédé suivant la revendication 3, dans lequel la chaîne est coupée suffisamment pour réduire de 80% environ cette contraction de la structure. 15
  5. Procédé suivant la revendication 3, dans lequel la chaîne est coupée de façon discontinue. 20
  6. Procédé suivant la revendication 1, dans lequel, après la coupe et avant l'opération (3), la structure sensiblement plane est laminée avec au moins un autre élément plan choisi dans le groupe comprenant d'autres structures sensiblement similaires et un métal conducteur, afin de former un stratifié. 25
  7. Procédé suivant la revendication 6, dans lequel, après stratification et avant l'opération (3), au moins un trou de traversée est exécuté dans le stratifié. 30
  8. Procédé suivant la revendication 1, dans lequel un circuit imprimé est appliqué à au moins une surface de la structure. 35
  9. Procédé suivant la revendication 6, dans lequel le stratifié présente au moins une surface extérieure de ladite structure sensiblement similaire à laquelle est appliqué un circuit imprimé. 40
  10. Procédé suivant la revendication 1, dans lequel la coupe est effectuée au moyen d'une lame. 45
  11. Procédé suivant la revendication 1, dans lequel la coupe est effectuée par l'application d'un rayonnement laser. 50
  12. Procédé suivant la revendication 1, dans lequel le tissu est un tissu de verre. 55
  13. Procédé suivant la revendication 1, dans lequel la résine est une résine époxy thermodurcissable.
1. Verfahren zur Herstellung von einem mit Harz impregnierten Textilerzeugnis ebener Struktur, das die folgenden Schritte aufweist:  
(1) Beschichten des Gewebes mit härtbarem Harz,  
(2) teilweises Härten des Harzes, und  
(3) vollständiges Härten des Harzes, dadurch gekennzeichnet,  
daß zwischen den Schritten (2) und (3) an wenigstens einer Stelle wenigstens eine Vielzahl der Kettfäden des Textilerzeugnisses geschnitten werden, wodurch die Schrumpfung der Struktur während des Schrittes (3) reduziert wird.
  2. Verfahren nach Anspruch 1, in dem Abschnitte des Gewebes des Textilerzeugnisses ebenfalls geschnitten werden.
  3. Verfahren nach Anspruch 1, in dem die Kettfäden entlang wenigstens einer Linie geschnitten werden, die im wesentlichen senkrecht zu den Kettfäden steht.
  4. Verfahren nach Anspruch 3, worin die Kettfäden ausreichend geschnitten werden, um die Schrumpfung der Struktur um ungefähr 80 % zu reduzieren.
  5. Verfahren nach Anspruch 3, worin die Kettfäden in einer nicht durchgehenden Art und Weise geschnitten werden.
  6. Verfahren nach Anspruch 1, worin nach dem Schneiden und vor dem Schritt (3) die im wesentlichen ebene Struktur mit wenigstens einem anderen ebenen Teil, das aus einer anderen im wesentlichen ähnlichen Struktur besteht, und einem leitfähigen Metall laminiert wird, um ein Laminat zu bilden.
  7. Verfahren nach Anspruch 6, worin nach der Laminierung und vor dem Schritt (3) wenigstens eine Durchgangsbohrung in dem Laminat hergestellt wird.
  8. Verfahren nach Anspruch 1, worin ein gedruckter Schaltkreis auf wenigstens einer Oberfläche der Struktur aufgebracht wird.
  9. Verfahren nach Anspruch 6, worin auf wenigstens einer äußeren Oberfläche der im wesentlichen ähnlichen Struktur des Laminats ein gedruckter Schaltkreis aufgebracht ist.
  10. Verfahren nach Anspruch 1, worin das Schneiden mittels einer Messerschneide durchgeführt

#### Patentansprüche

wird.

11. Verfahren nach Anspruch 1, worin das Schneiden durch die Anwendung von Laserstrahlen bewirkt wird. 5
12. Verfahren nach Anspruch 1, worin das Textilerzeugnis ein Glasgewebe ist.
13. Verfahren nach Anspruch 1, worin der Harz ein wärmehärtbarer Epoxydharz ist. 10

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FIG. 1

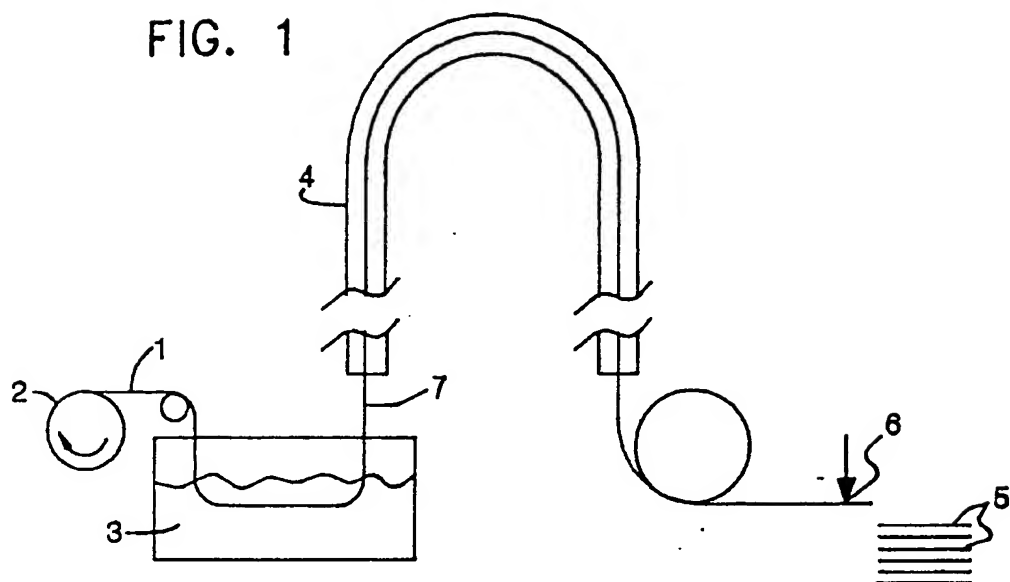


FIG. 2

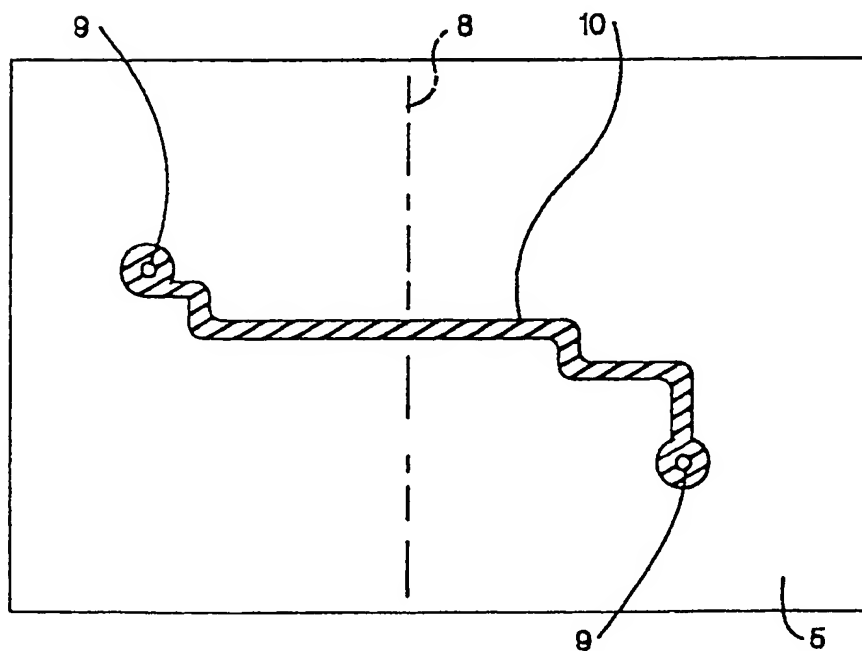




FIG. 3

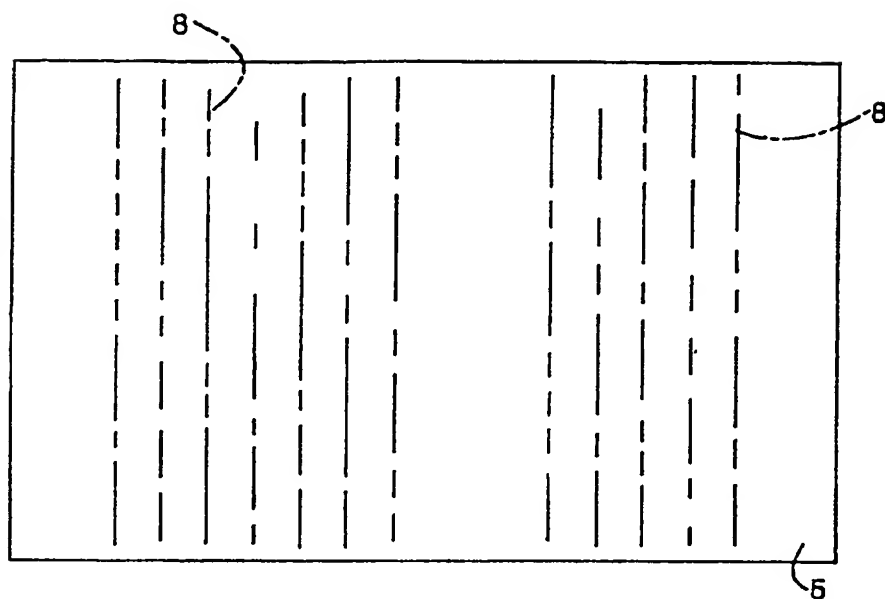


FIG. 4

